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71 Applicant: **WESTINGHOUSE ELECTRIC CORPORATION**
Westinghouse Building Gateway Center
Pittsburgh Pennsylvania 15222(US)

72 Inventor: **Fero, Arnold Hill**
R.D. 2, Box 374 Leechburgh Rd
New Kensington, PA 15068(US)

74 Representative: **van Berlyn, Ronald Gilbert**
23, Centre Heights
London, NW3 6JG(GB)

54 **Nuclear power generating station equipment qualification monitoring method and apparatus.**

57 Apparatus (10) for monitoring an object piece of qualified equipment in a nuclear power plant includes passive means for detecting a total integrated dose of radiation received by the object piece, means for projecting a thermal history of the object piece, and means for housing the passive detection means and projection means in close proximity to the object piece. In order to generate and maintain evidence to assure that qualified equipment used in such stations will operate on demand, the passive detection means and projection means mounted in close proximity to the object piece are exposed to the environment of a normally operating power plant and periodically analyzed to determine whether the qualified life of the object piece may be extended.

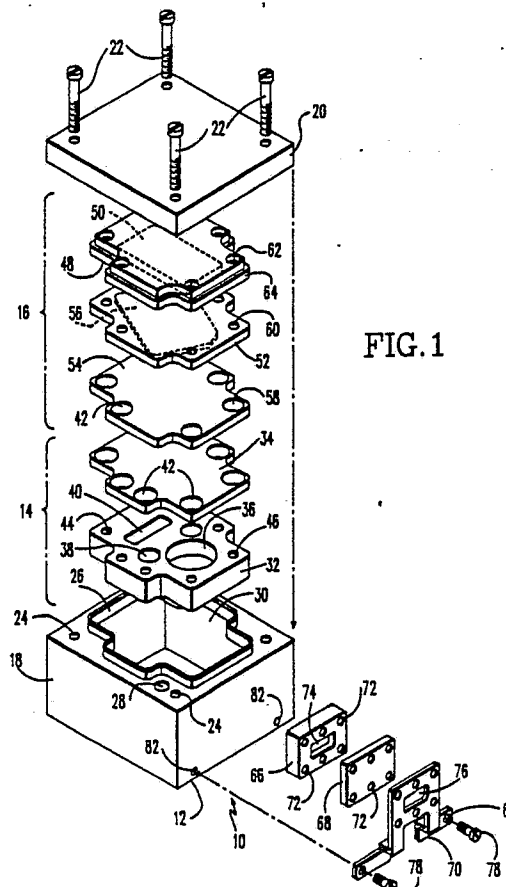


FIG. 1

NUCLEAR POWER GENERATING STATION EQUIPMENT QUALIFICATION MONITORING METHOD AND APPARATUS

This application is related to a nuclear power generating station, method and apparatus for monitoring thereby generating and maintaining evidence to assure that qualified equipment used in such stations will operate on demand in order to meet system performance requirements.

Safety system equipment in nuclear power generating stations is required to be capable of performing satisfactorily under defined conditions, including postulated design basis events such as a loss of coolant accident. It is necessary to provide assurance that such equipment meets its performance requirement throughout its installed life. This is accomplished through a disciplined program of design, qualification, production quality control, installation, maintenance, and surveillance testing.

The process of qualification usually also establishes the qualified lifetime of the equipment. That is the period of time, prior to the start of a design basis event, for which the equipment is demonstrated to meet the design requirements for the specified service conditions. At the end of qualified lifetime, such equipment should be capable of performing the safety functions required for the postulated design basis, and post-design basis events. The qualified or safe lifetime of equipment may be allowed to be extended if it can be shown that the service or environment conditions originally assumed were overly conservative with respect to the conditions that apply at the equipment's real installed location. Use of extension methods requires documentation of the program to be followed and auditable records of the results.

Gamma ray and beta radiation exposure occurring during normal nuclear power plant operations, or occurring as a result of an accident, can alter the performance of certain equipment such as motors, valve and motor operators, transmitters, indicators, instruments, organic fluids, seals, and electrical insulation. For this reason, equipment qualification includes appropriate exposure to radiation as part of the test procedure. The total radiation dose to which the equipment is exposed in qualification-testing depends upon the expected normal radiation environment and the length of time following an accident that the equipment is required to operate.

Nuclear power plant personnel will require a knowledge of the total integrated radiation dose that a piece of equipment has received if it is desired to extend the equipment qualification beyond the present qualified life, or if it is desired to requalify equipment following an accident. In gen-

eral, the radiation doses used for equipment qualification are sufficiently conservative that, if the actual integrated doses are known, the equipment could continue in service without exceeding the existing qualification envelopes. This is particularly true for an accident where the distribution of radiation levels in the nuclear power plant will vary widely, and be much lower than that assumed for qualification, due to radioactive decay during the release, the physical distribution of radioactive material, and the presence of local shielding in the form of structure, other equipment, floors, and walls.

Previously, nuclear power plant personnel would have very few options with regard to thermal and radiation aging of important equipment. Qualified equipment could be replaced when it reached the end of its qualified lifetime in calendar years without regard to the actual environmental aging; or, nuclear power plant life extension decisions and decisions regarding qualified equipment could be made based upon a projection of very limited active temperature and radiation level measurements. Without measured data, the affected equipment could either be replaced, refurbished, or disassembled, inspected, and reassembled. Major problems with such approaches, however, exist in the time and cost for replacement or refurbishment, as well as considerations affecting qualified equipment vendors and qualified repair parts. Therefore, what is needed is a passive system that provides integrated radiation dose and thermal history throughout normal plant operation, through the duration of a nuclear power plant accident, and beyond.

One such passive system is disclosed in European Patent Application No. 0312247A2 dated October 5, 1988. However, the apparatus and methods according to one of the embodiments disclosed and claimed therein required a holder which is not only expensive and difficult to initially fabricate, but is also difficult to service in the field. In addition, it has been found that a much more limited amount of space is available for mounting such passive systems, and that the particular methods for mounting such passive systems were exceedingly difficult.

Accordingly, it is a general object of the present invention to provide improved methods and apparatus for monitoring the life span of equipment installed in a nuclear power plant. More specifically, it is an object of the present invention to provide an improved passive system capable of indicating total integrated radiation dose and ther-

mal history of an object piece of qualified equipment throughout normal nuclear power plant operation, through the duration of a nuclear power plant accident, and beyond.

The present invention also provides (i) data to support continued use of qualified equipment following an accident; (ii) data to support nuclear power plant life/license extension applications; (iii) data to support an observation that an object piece of qualified equipment has not yet reached the end of its qualified life.

The present invention demonstrates utility management prudence with regard to an integrated equipment surveillance program, pre-planning for nuclear power plant lifetime/license extension (PLEX), and a commitment to post-accident nuclear power plant recovery.

It is the specific object of the present invention to provide an improved holder for such passive system in order to accomplish the above stated objects, such holder being small, relatively inexpensive and easy to fabricate, easy to mount and service in the field, and capable of providing a redundant sealing of the measurement devices contained therein.

The invention resides in the passive detection means which includes first dosimetry means for measuring a gamma ray dose, and second dosimetry means for measuring a beta ray dose. The projection means includes first monitor means for determining a peak temperature experienced by the object piece, and second monitor means for determining an integrated thermal exposure to the object piece. The housing means consists of an inexpensive, sealed, diecast aluminum box which is easily riveted to a wide variety of mounting brackets that are conventionally used in nuclear power generating stations. In order to minimize the size of the improved passive system and permit it to be housed within such boxes, the first and second dosimetry means are assembled from injection-molded parts and are self-sealing when so assembled.

The invention is practiced by the method of monitoring the object piece in accordance with a preferred embodiment which includes the steps of mounting such passive detection means and projection means in close proximity to the object piece, exposing such mounted means to the environment in a normally operating nuclear power plant, and periodically analyzing the first and second dosimetry means and first and second monitor means to determine whether the qualified life of the object piece may be extended. Since an outer portion of the housing means, as well as both of the first and second dosimetry means include encoded indicia, such indicia are also checked in performing the method in accordance with the pre-

ferred embodiment to confirm that the correct monitor is being serviced, and to account for the data contained therein.

The invention has the advantages of monitoring an object piece of qualified equipment in a nuclear power plant which by passive means and detecting a total integrated dose of radiation received by an object piece and projecting a thermal history of the object piece and housing the passive detector and thermal history protector in close proximity to the object piece.

The invention will become more readily apparent from the following description of the preferred embodiment thereof, shown by way of example only, in the accompanying drawings wherein:

Figure 1 is an exploded view of an improved monitor according to the present invention;

Figure 2 is a top view of a holder portion of a long-term monitor block in accordance with a first embodiment of the present invention;

Figure 3 is a sectional view of the holder portion shown in Figure 2 taken along the lines 3-3;

Figure 4 is a top view of a cover plate portion of the long-term monitor block;

Figure 5 is a sectional view of the cover plate portion shown in Figure 4 taken along the lines 5-5;

Figure 6 is a top view of a holder portion of a long-term monitor block in accordance with a second embodiment of the present invention;

Figure 7 is a sectional view of the holder portion shown in Figure 6 taken along the lines 7-7;

Figure 8 is a top view of a first holder portion of a short-term monitor block in accordance with a first embodiment of the present invention;

Figure 9 is a side view of the first holder portion shown in Figure 8;

Figure 10 is a top view of a first holder portion of a short-term monitor block in accordance with a second embodiment of the present invention;

Figure 11 is a side view of the first holder portion shown in Figure 10;

Figure 12 is a top view of a second holder portion of the short-term monitor block;

Figure 13 is a side view of the second holder portion shown in Figure 12;

Figure 14 is a top view of a cover plate portion of the short-term monitor block;

Figure 15 is a sectional view of the cover plate portion shown in Figure 14 taken along the lines 15-15;

Figure 16 is a top view of a block portion of a beta dosimeter assembly in accordance with the present invention;

Figure 17 is a sectional view of the block portion shown in Figure 16 taken along the lines 17-17;

Figure 18 is a front view of a holder portion of the beta dosimeter assembly in accordance with the present invention;

Figure 19 is a side view of the holder portion shown in Figure 18;

Figure 20 is a front view of a mounting bracket used to mount the improved monitor in accordance with a first embodiment of the present invention;

Figure 21 is a side view of the mounting bracket shown in Figure 20;

Figure 22 is a front view of a mounting bracket used to mount the improved monitor in accordance with a second embodiment of the present invention;

Figure 23 is a front view of a first portion of a mounting bracket used to mount the improved monitor in accordance with a third embodiment of the present invention;

Figure 24 is a front view of a second portion of the mounting bracket in accordance with the third embodiment of the present invention;

Figure 25 is a side view of the second portion of the mounting bracket shown in Figure 24;

Figure 26 is a front view of a compression spring catch that is used in conjunction with the first and second portions of the mounting bracket in accordance with the third embodiment of the present invention;

Figure 27 is a side view of the compression spring catch shown in Figure 26; and

Figure 28 is a block diagram that illustrates the method according to the present invention.

Referring now to the drawings, wherein like characters refer to like or corresponding parts throughout each of the views, there is shown in Figure 1 an exploded view of an improved monitor 10 in accordance with the present invention. As is conventional, the monitor 10 is typically mounted within the containment of a nuclear power generating station in close proximity to an object piece of equipment (not shown) which is "qualified", such as equipment that is qualified in accordance with WCAP-8587, Revision 6-A (NP), entitled "Methodology for Qualifying Westinghouse WRD Supplied NSSS Safety-Related Electrical Equipment", approved by the U.S. Nuclear Regulatory Commission on November 10, 1983, available to the public from Westinghouse Electric Corporation, Power Systems, Box 355, Pittsburgh, Pennsylvania 15230, USA, and incorporated herein by reference.

As is shown in greater detail in Figures 2-19, when considered in conjunction with Figure 1, the monitor 10 is generally comprised of a die-cast aluminum box 12 containing first dosimetry means for measuring a gamma ray dose, and second dosimetry means for measuring a beta ray dose, the first and second dosimetry means together

comprising passive means for detecting a total integrated dose of radiation received by the object piece (not shown). Including a body portion 18 and a cover portion 20, the box 12 is substantially corrosion-proofed by essentially excluding any copper from the aluminum alloy used to cast the body portion 18 and cover portion 20. One such suitable box is manufactured by Rose Enclosures of Rockville, Maryland, USA, as a Type 01.060603.

As is shown in Figure 1, the cover portion 20 of the box 12 is fitted with a plurality of stainless steel captive screws 22 which are formed to engage corresponding threaded holes 24 in the body portion 18. Sealing of the cover portion 20 to the body portion 18 is provided by a tongue 26 in the body portion 18 for engagement with a correspondingly formed groove (not shown) in the underside of the cover portion 20. Fastening channels 28 are also provided outside of the sealed area comprising a cavity 30 within the body portion 18. Any one of several conventional radiation and temperature resistant seal materials may also be incorporated in a crush seal geometry.

The first dosimetry means consists of a long-term monitor block 14 and a short-term monitor block 16, the component parts of which are formed to fit within the cavity 30 in the body portion 18 of the box 12. Each of the component parts of the long-term monitor block 14 and the short-term monitor block 16 are preferably formed in accordance with a first important aspect of the present invention by injection molding of polyetheretherketone (PEEK), preferably a polyetheretherketone thermoplastic such as Arlon 1000, manufactured by Greene, Tweed Engineered Plastics, Harleysville, Pennsylvania, USA.

It has been found that PEEK is the only suitable material which exhibits the required combination of properties of low density, ease of molding, high service temperature, radiation resistance, and resistance to high temperature steam and post-LOCA caustic environments. As is well known, "LOCA" refers to a loss of coolant accident.

Referring now specifically to Figures 1-7, it can be seen that the long-term monitor block 14 comprises a holder portion 32 and a cover plate portion 34. As is shown in Figures 2 and 3, the holder portion in accordance with a first embodiment of the present invention includes a large cylindrical cavity 36 for containing a neutron detecting solid state track recorder (not shown), two smaller cylindrical cavities 38 for containing thermal integrating solid state track recorders (not shown), and an elongated cavity 40 for containing a plurality of optical crystals (not shown). Preferably, the elongated cavity 40 is formed to contain at least three lithium fluoride (LiF) optical crystals as are described more particularly in European Patent Ap-

plication 0312247A2 dated October 5, 1988.

Alternatively, and referring now to Figures 6 and 7, a holder portion 84 in accordance with a second embodiment of the present invention includes the large cylindrical cavity 36 for containing a neutron detecting solid state track recorder (not shown), the elongated cavity 40 for containing a plurality of optical crystals (not shown), and another somewhat smaller cylindrical cavity 86 for containing another neutron detecting solid state track recorder. In accordance with this second embodiment of the present invention, the cavities 36 and 86 are differently sized because the neutron detecting solid state track recorder which is adapted to be contained in cavity 36 is cadmium shielded, while the other neutron detecting solid state track recorder that is adapted to be contained in cavity 86 is bare.

The cover portion 34 shown in Figures 4 and 5 is adaptable for covering either of the holder portions 32 or 84, and includes a plurality of countersunk holes 42 which are adapted to receive means such as conventional flat head, hex-socket cap screws (not shown) for joining such cover portion 34 to the holder portion 32 or 84. Correspondingly located holes 44 are formed in the holder portion 32 or 84 and are provided with stainless steel threaded inserts 46 for receiving the cap screws (not shown).

Referring now specifically to Figures 1 and 8-15, it can be seen that the short-term monitor block 16 comprises a first holder portion 48 having a large rectangular cavity 50 formed therein which is adapted to contain one or more conventional peak temperature monitors (not shown), a second holder portion 52, and a cover plate portion 54. The second holder portion 52 also includes a large rectangular cavity 56 which is adapted to contain one or more conventional thermoluminescent dosimeters (not shown). In accordance with a second important aspect of the present invention, the cavity 56 formed in the second holder portion 52 is formed so as to be capable of containing the thermoluminescent dosimeters (not shown) in a conventional aluminum Harshaw card.

As shown in Figures 8 and 9, the first holder portion 48 is adapted to contain only the peak temperature monitors within cavity 50. However, in accordance with the second embodiment of the present invention where the holder portion 84 of the long-term monitor block 14 is used, an alternative first holder portion 88 is employed to accommodate two thermally integrating solid state track recorders (not shown) in a pair of small cylindrical cavities 38 as shown in Figure 10.

The short-term monitor block 16 is, as shown in Figure 1, assembled by first inserting the various detection means within their respective cavities,

and second sandwiching the second holder portion 52 between the first holder portion 48 and the cover plate portion 54. The cover plate portion 54 shown in Figures 14 and 15 is adaptable for use with either of the first holder portions 48 or 88, as well as the second holder portion 52, and includes a plurality of countersunk holes 58 which are adapted to receive means such as the conventional flat head, hex-socket cap screws (not shown) referred to herein above for joining such cover plate portion 54 to the first holder portions 48 or 88 and the second holder portion 52. Correspondingly located holes 44 are formed in the first holder portion 48 or 88 and are provided with stainless steel threaded inserts 62 for receiving the cap screws (not shown), via correspondingly located holes 60 in the second holder portion 52. As is shown in Figures 9 and 11, both of the first holder portions 48 and 88 include a shoulder 64 that is formed about their peripheries to accommodate such holder portions 48 and 88 within the cover portion 20 of the box 12.

Referring now to Figures 16-19 in conjunction with Figure 1, it can be seen that the second dosimetry means comprises a beta dosimeter assembly including a beta block 66, a thin (e.g., approximately .00254 cm (0.001 inch) thick and less than 20 mg/cm²) stainless steel foil beta window 68, and a holder portion 70. The beta dosimeter assembly consisting of the beta block 66, beta window 68, and holder portion 70 is held together in a sealed relationship by screws (not shown) threaded through holes 72 bored in the beta block 66, beta window 68, and holder portion 70. As is conventional, the holes 72 formed in the beta block 66 may be threaded, or the beta dosimeter assembly may be fastened together with stainless steel blind rivets (not shown).

Two LiF optical crystals (not shown) are placed within a cavity 74 that is formed in the beta block 66, such that they may be exposed to beta and low energy gamma ray radiation through the beta window 68 and a hole 76 formed in the holder portion 70. In such a manner, the beta/low energy gamma ray dose may be obtained by conventional subtraction techniques since the higher energy gamma ray radiation is measured by the LiF optical crystals contained within the long-term monitor block 14. A pair of screws 78 conveniently retain the beta dosimeter assembly against a side of the box 12, threaded through holes 80 formed in the holder portion 70 into corresponding threaded holes 82 in the box 12.

The LiF optical crystals comprise color-center formation means. Ionizing radiation, as is well known, produces relatively stable color-centers in lithium fluoride, and the values of the optical absorbance of the maxima of the resulting absorption

bands can be measured at a plurality of discrete wavelengths. The principle of color-center formation as a radiation dosimeter involves exposure to ionizing radiation which results in trapped electrons in negative ion vacancies in the lattice. These trapped electrons are responsible for the optical absorbance phenomenon known as "color-centers".

As is well known, a series of color-centers are developed in lithium fluoride with increasing radiation dose. See, for example, "Electron and Gamma-Ray Dosimetry Using Radiation-Induced Color Centers in LiF", McLaughlin, a technical paper presented at the Second International Meeting on Radiation Processing, Miami, Florida, USA in 1978. By utilizing absorption bands corresponding to different types of color-centers, an absorbed dose range from 10^3 to 10^{10} rads can be covered, with response regions overlapping at the doses of change-over from one to the other center.

The production of each type of color-center is initially proportional to absorbed dose, and then gradually tends towards saturation. Each of the LiF optical crystals is read by measuring the amount of optical absorbance at wavelengths which correspond to the various color-centers of interest. This measurement may be made using any commercially available UV-Vis spectrophotometer, with one suitable such spectrophotometer being made by Varian Instrument Division, Sunnyville, California, USA as the model TMS 200.

The amount of optical absorbance determined by the spectrophotometer is then compared to a calibration curve to determine the absorbed dose. It should be noted at this juncture that such reading of the LiF optical crystals does not alter the color-centers themselves. Therefore, each LiF optical crystal constitutes a rereadable permanent record. A presently preferred form for the lithium fluoride dosimeter is as a cleaved lithium fluoride crystal that is commercially available from the Harshaw Chemical Company, Solon, Ohio, USA.

The thermoluminescent dosimetry means (TLD) comprises in a presently preferred embodiment at least one conventional manganese activated calcium fluoride thermoluminescent dosimeter capable of providing gamma-ray dose information below approximately 10^5 rads. On the other hand, the neutron detecting solid state track recorders consist of reusable deposits of fissionable material on high purity nickel backing disks in surface contact with replaceable mica. As is known, neutron-induced fission in isotopes of uranium, plutonium, and neptunium produces latent fission-fragment tracks in the SSSTR. Such tracks are developed by chemical etching to a size that is observable with an optical microscope for track counting. Both bare and cadmium-shielded isotopes of U-235

and Pu-239 may be used, as well as cadmium-shielded U-238 and Np-239.

The peak temperature monitors are preferably comprised of conventional monitors that irreversibly turns black when an indicated peak temperature is reached. One suitable such type of monitor is the "Omegalabel" temperature labels manufactured by Omega Engineering, Incorporated, Stamford, Connecticut, USA.

On the other hand, the thermal integrating solid state track recorders may comprise any such means that is adapted for use as integrating thermal monitors. As is well known, solid state track recorders which have been exposed to a fission source contain a known number of fission fragment tracks. These tracks are damaged areas that can be chemical etched to an observable size for optical or spark counting. Such damaged zones are self-repairing by annealing upon exposure of the solid state track recorded to elevated temperatures. The rate and amount of repair is a function of the material and the duration at the elevated temperature and may be characterized by an Arrhenius function of temperature. One such process for measuring temperature with solid state track recorders is disclosed in U.S. Patent No. 4,167,109, issued September 11, 1979 to Gold.

According to Gold, mica or quartz track detectors may be used to measure temperature by first exposing the track detector to a known number of fission fragments, placing the track detector in an unknown temperature environment for a length of time T, and measuring the track dimetral change or change in number of tracks observed. As is known, the loss in tracks, is a function of temperature and time of exposure. Since the temperature dependency is quite short, in general all tracks will be removed or amended within a very short time if T is greater than T_0 , and none will be removed if T is less than $T_0 - T$. Only in the region between $T_0 - T$ and T_0 will a fairly precise definition of exposure temperature occur. The temperature T_0 for typical track detector materials has only a few values which do not necessarily correspond to temperature in a desired measurement range for applications with the monitor 10.

Since T_0 in general related closely to the melting point of the track detector, use of various plastic and glass types with different melting points will provide a range of temperatures to satisfy almost any need. Once a specific type of plastic or glass is calibrated for response to temperature and annealing, the degree of accuracy of the temperature measurement averaged over time can be ascertained.

A method of monitoring the object piece of equipment which utilizes apparatus in accordance with the monitor 10 includes the steps of mounting

the above described passive detection means and projection means in close proximity to the object piece, exposing such mounted means to the environment of a normally operating nuclear power plant, and periodically analyzing the passive detection means and projection means to determine whether the qualified life of the object piece may be extended.

Referring now to Figures 20-27, there is shown a variety of mounting means suitable for use with the monitor 10. One mounting bracket 90 is shown in Figures 20 and 21, and is suitable for mounting the monitor 10 directly to a surface such as mirror insulation or a cubicle wall in a nuclear power generating station. The mounting bracket 90 preferably comprises a piece of 16-gauge stainless steel sheet which is cut to form and bent as shown. A pair of holes 92 suitably sized for conventional attachment means such as blind rivets are punched or drilled in the sheet 90 at positions which correspond to the fastening channels 28 (Figure 1) formed in the body portion 18 of the box 12. A plurality of holes 94 are likewise provided to attach the mounting bracket 90 coupled to the monitor 10 directly to the surface by means such as screws (not shown).

Because of the widespread use in nuclear power generating stations of an all purpose metal framing channel known as UNISTRUT® the mounting means that is shown in Figures 22-27 is specifically adapted for use with such UNISTRUT® channeling. The mounting bracket 96 shown in Figure 22, for example, is preferably formed of 16-gauge stainless steel sheet and includes a pair of holes 98 for use in the same manner as the holes 92 in the mounting bracket 90. Another pair of holes 100 is provided at an interval that is adapted for bolting of the mounting bracket 96 (with the monitor 10 attached thereto) to the UNISTRUT® channeling.

In an environment of high-radiation, mounting means that is specifically adapted for quick service is shown in Figures 23-27. A first portion 102 (Figure 23) of a mounting bracket that is adapted for such quick service includes a pair of holes 104 which, like the holes 100 of Figure 22, are provided at an interval that is adapted for bolting of the first portion 102 to the UNISTRUT® channeling. An elongated hole 106 and a pair of small holes 108 are also provided to interact in conjunction with a second portion 110 (Figures 24 and 25) of the mounting bracket and a conventional compression spring catch 114 (Figures 26 and 27) as is explained in greater detail herein below.

The second portion 110 of the mounting bracket according to this embodiment of the present invention is also preferably comprised of 16-gauge stainless steel formed in a substantially S-shape as shown in Figure 25 so that an upper "hook" of the

second portion 110 is adapted to be engaged to the hole 106 in the first portion 102 of the mounting bracket. A lower "hook" of the second portion 110 is likewise adapted to be engaged to the crossbar portion of the compression spring catch 114 as shown in Figures 26 and 27.

While the particular separation of the hole 106 from the pair of holes 108 depends upon the pulling force of the compression spring catch 114 employed (i.e., the greater the force of the compression spring catch, the greater is such separation), one suitable such compression spring catch 114 is the No. HC 83314-42-LALB-SS catch that is manufactured by Nielsen Hardware Corporation of Hartford, Connecticut, USA.

Referring now to Figure 28, there is shown a monitor 10 that is mounted in close proximity to an object piece in a nuclear power generating station. The monitor 10 is shown attached to the mounting bracket 90 which is, in turn, attached by a plurality of screws 116 to a wall. An encoded label 120 (e.g., a bar-coded label as shown) is affixed to the monitor 10 for identification thereof.

The encoded label 120 is first scanned by a worker 122 by any conventional means such as an infrared bar code scanning wand 124. In one possible embodiment of the present invention, the wand 124 is connected by a flexible cord 126 to a bar code reader 128 which is, for example, carried on the worker's belt. A suitable such infrared bar code scanning wand 124 and bar code reader 128 is manufactured by Intermec of Lynnwood, Washington, USA, as their Models 1236 and 9410, respectively.

Thereafter, the data thusly read is stored by the reader 128 until, at a subsequent time, it is connected by way of a multiple conductor cable 130 to an interface 132, such as the Model 9401 that is also manufactured by Intermec, which utilizes conventional RS-232C interface protocol to transmit the data to a host computer 134 for analysis.

A second method of inputting data is substantially similar to the method described immediately herein above, but employs a hand-held laser scanner 140 such as the Model 1600 that is also manufactured by Intermec. As is also shown in Figure 28, the scanner 140 is used to scan encoded labels 138, 144 affixed respectively to the short term monitor block 16 and long-term monitor block 14. This method has several advantages, mainly in that no physical contact is required between the scanner 140 and the encoded label 138 or 144.

As a rule, however, it would be undesirable to have two different scanners in use. In any case, the scanner 140 is conventionally connected to a suitable reader 142 (such as the Intermec Model 9500)

that is also connected by way of an RS-232C interface for communication of the data to the host computer 134.

According to a periodic inspection routine, the worker 122 would merely remove the cover portion 20 of each monitor 10 after having verified the identification of that monitor 10 by scanning the encoded label 120 as described above. Once the cover portion 20 of the box 12 has been so removed, the worker would similarly scan in turn the encoded label 138 of the short-term monitor block 16 followed by the encoded label 144 of the long-term monitor block 14.

One, or both, of the inspected and scanned monitor blocks 14 and 16 would then be replaced with new such monitor blocks 14 or 16, and the encoded labels 138, 144 of such new monitor blocks 14, 16 would also be scanned to verify their proper replacement. An encoded label (not shown) could also be placed on the beta dosimeter assembly consisting of the beta block 66 and beta window 68 such that the beta dosimeter assembly could likewise be periodically scanned, inspected and replaced.

Upon visual examination, if the lid seal (not shown) between the body portion 18 and the cover portion 20 of the box 12 showed any sign of deterioration, a replacement cover portion 20 with a new seal could be installed by the worker 122. The old cover portion 20 would then be refurbished with a new seal and returned to a spares inventory. It should also be noted at this juncture that all of the component parts of the monitor 10, because of their selected sizes and materials, can be readily decontaminated.

The advantages afforded by the apparatus in accordance with the present invention include ease of manufacture, assembly, handling and marking. A combination of the relatively thin (i.e., approximately 0.1 inch thick) aluminum enclosure and the mass of the PEEK not only effectively shields the LiF optical crystals and thermoluminescent dosimeters from external beta radiation fields, but it also minimizes the generation of Bremsstrahlung radiation through the utilization of low atomic number materials. Such low atomic materials also minimize attenuation of neutron and gamma ray radiation, thereby simplifying calibration. Moreover, the various monitor blocks serve to establish electron equilibrium conditions which satisfy requirements of Bragg-Gray small cavity theory, and the overall mass of the materials used provides some thermal inertia which reduces any undesirable sensitivity to brief thermal spikes in the environment.

Obviously, many modifications are possible in light of the above teachings. It should be understood, therefore, that within the scope of the appended claims, the present invention may be prac-

ticed otherwise than as specifically described herein without departing from the scope of the claims.

5 Claims

1. Apparatus (10) for monitoring an object piece of qualified equipment in a nuclear power plant, said apparatus comprising:
 - passive means for detecting a total integrated dose of radiation received by the object piece, said passive detection means including first dosimetry means for measuring a gamma ray dose and second dosimetry means for measuring a beta ray dose;
 - said first dosimetry means comprising color-centered formation means for measuring said gamma ray dose in a range of from approximately 10^3 rads to 10^{10} rads, thermoluminescent dosimetry means for measuring said gamma ray dose in a range of from 10 rads to approximately 10^5 rads;
 - means for determining a thermal history of the object piece;
 - means for housing said passive detection means and said means for determining said thermal history in close proximity to the object piece; and
 - means for holding (32, 84) said color-centered formation means and said thermoluminescent means within said housing means, said holding means being adapted to establish an electron equilibrium condition which satisfies requirements of Bragg-Gray small cavities, characterized in that:
 - said holding means (32, 84) comprises a (12) box including a body portion (18) defining a cavity (36, 38, 40, 86) and a cover portion (20, 34) adapted to seal said cavity (36, 38, 40, 86) and means molded to conform to the shape of said cavity (36, 38, 40, 86).
2. The apparatus according to claim 1, wherein said retaining means is further characterized in comprising:
 - a beta block (66) having formed therein a groove to contain said pair of optical crystals;
 - means for protecting (68) said pair of optical crystals from environmental hazards due to temperature and radiation, said protection means (68) having a predetermined low mass thickness in order to minimize attenuation of beta rays; and
 - a retainer plate having formed therein a beta window (68) comprised of a slot of dimensions corresponding generally to said cavity (30) formed in said beta block (66), wherein said retainer plate is connected through said protection means to said beta block (66) in such a manner as to register said beta window (68) with said cavity (74) containing said pair of optical crystals.
3. A method of monitoring an object piece of

qualified equipment in a nuclear power plant, comprising the steps of:

providing passive means for detecting a total integrated dose of radiation received by the object piece;

providing a means for projecting a thermal history of the object piece;

housing said passive detection means and said projection means in close proximity to the object piece;

characterized in the further steps of:

labeling said passive detection means with an encoded label (138) for identification thereof;

labeling said projection means with an encoded label (144) for identification thereof;

periodically inspecting said passive detection means and said projection means by scanning their respective labels (138, 144) to determine their identification; and

replacing said passive detection means and said projection means.

4. The method according to claim 3, wherein said first providing step is characterized in the further steps comprised of:

measuring a gamma ray dose with first dosimetry means including color-center formation means for measuring said gamma ray dose in a first predetermined range, thermoluminescent dosimetry means of or measuring said gamma ray dose in a second predetermined range; and means for holding said color-center formation means and said thermoluminescent dosimetry means within said housing means, said holding means being adapted to establish an electron equilibrium condition which satisfies requirements of Bragg-Gray small cavities; and

measuring a beta ray dose with second dosimetry means including a pair of lithium fluoride optical crystals and means for retaining said pair of optical crystals upon an exterior portion of said housing means.

5. The method according to claim 3, further characterized in comprising the step of detecting neutron-induced fission with at least one solid state track recorder.

6. The method according to claim 3, wherein said second providing step is characterized in the further steps comprised of:

determining a peak temperature experienced by the object piece with first monitor means including at least one non-reversible temperature label; and determining an integrated thermal exposure to the object piece with second monitor means including a plurality of solid state track recorders (SSTR).

7. The method according to claim 6, wherein said second determining step is further characterized in comprising the step of pre-exposing said SSTRs to a fission source to produce a predeter-

mined nuclear of fission fragment tracks which upon subsequent exposure to an elevated temperature are annealed at a rate corresponding to an Arrhenius function of temperature.

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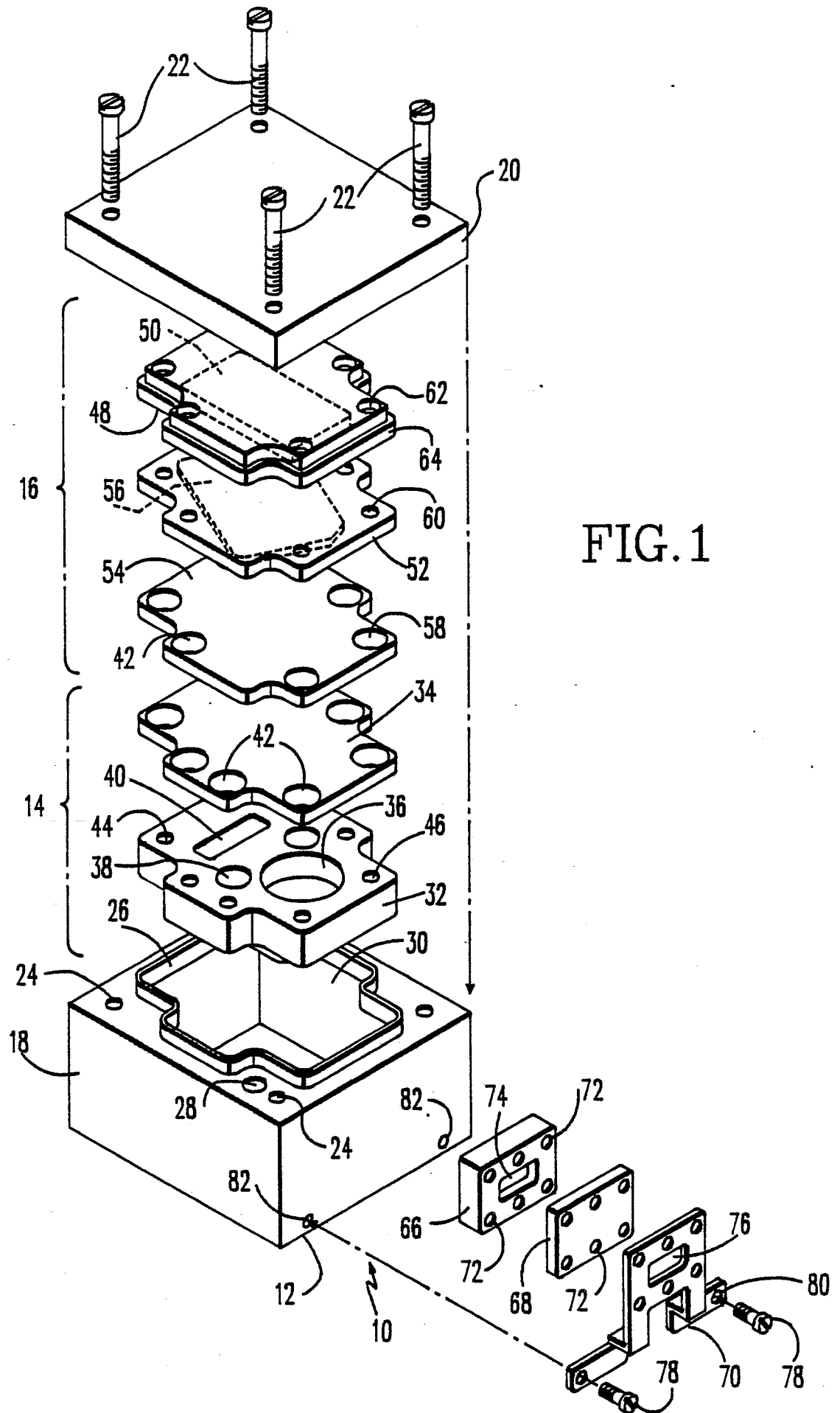
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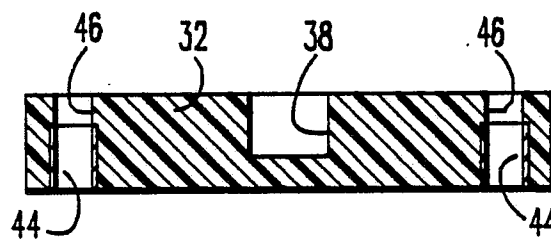
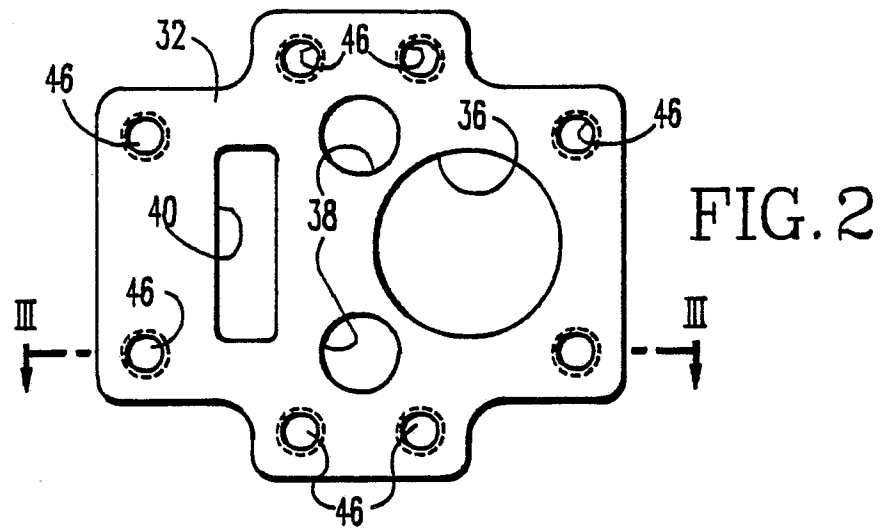


FIG. 3

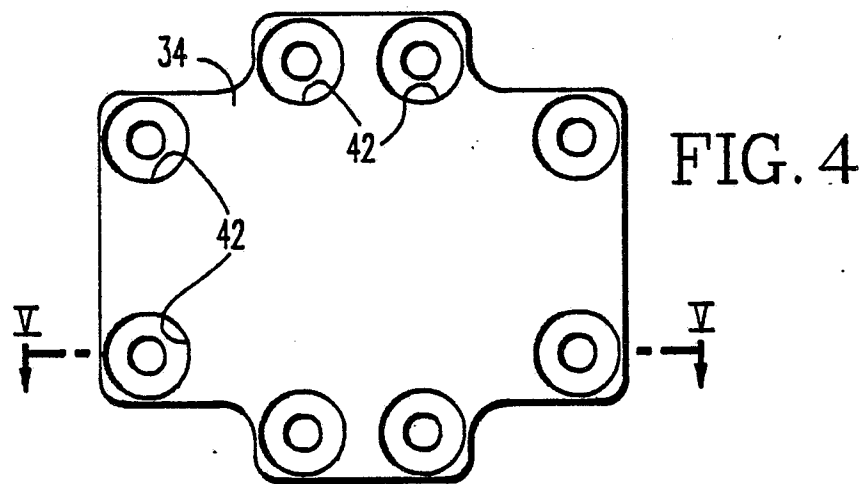


FIG. 5

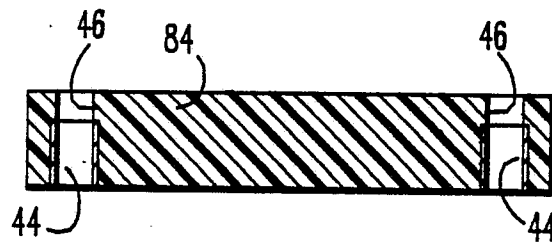
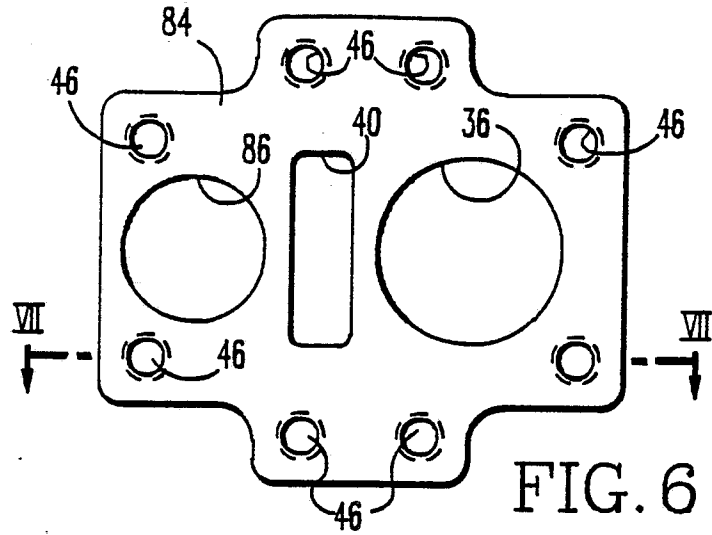


FIG. 7

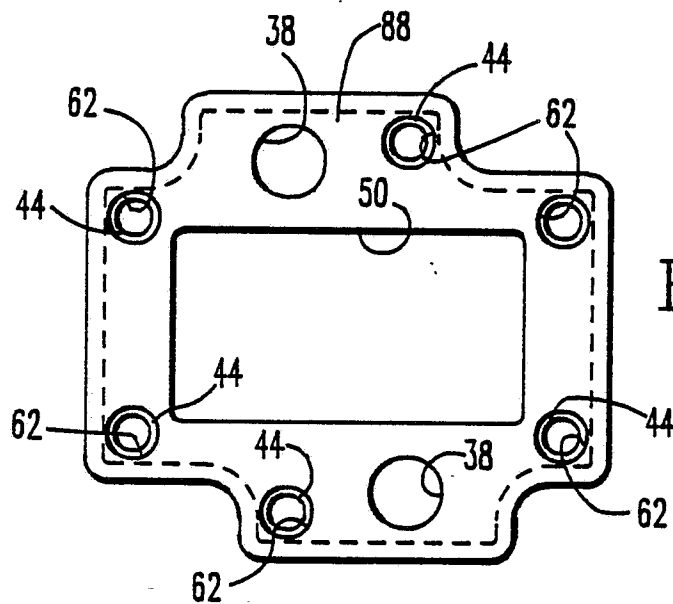


FIG. 10

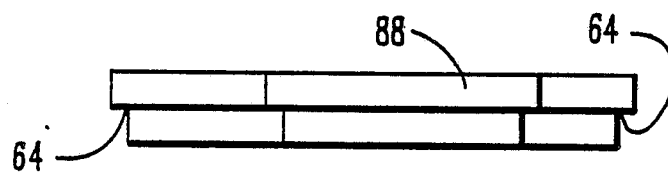
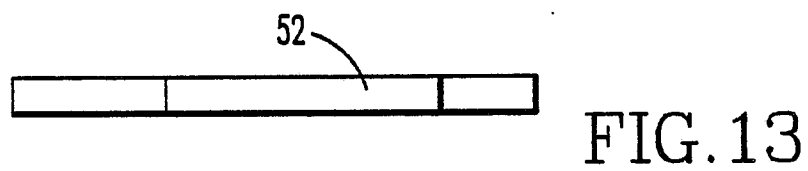
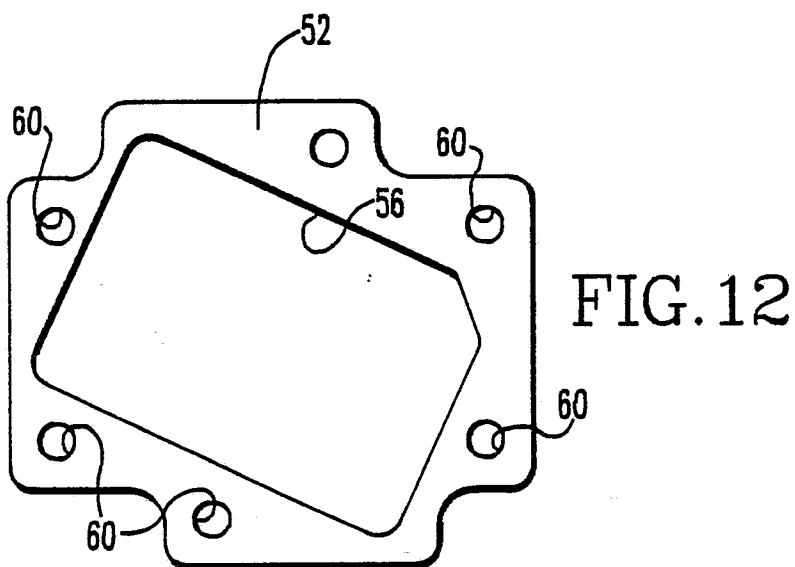
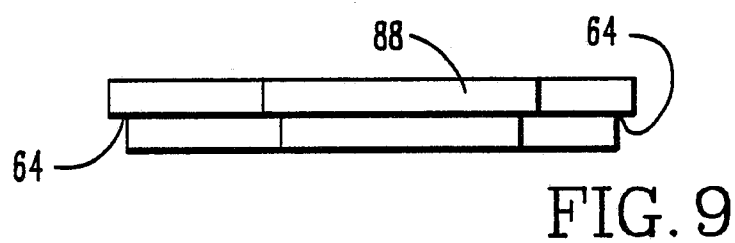
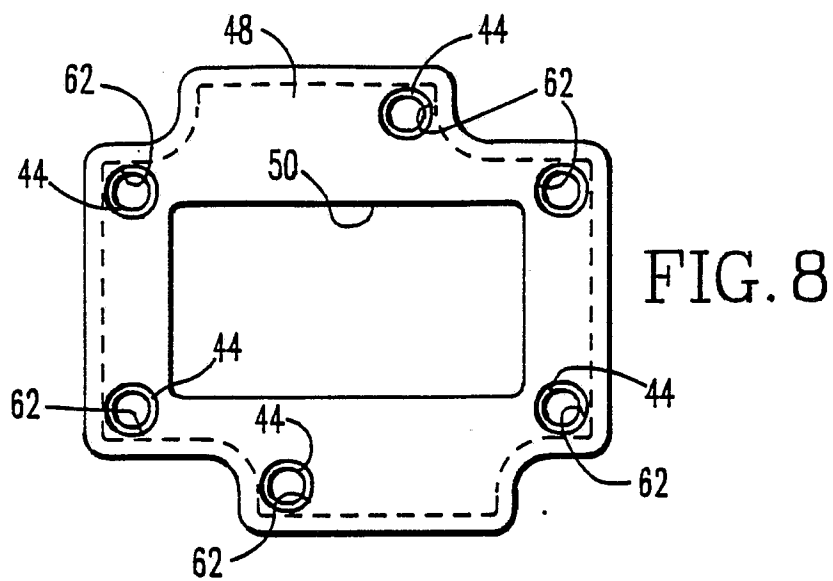
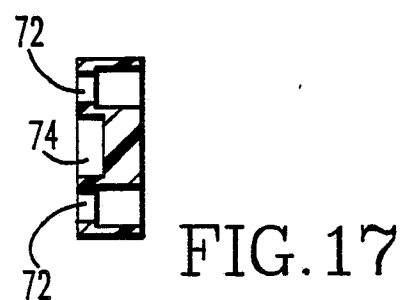
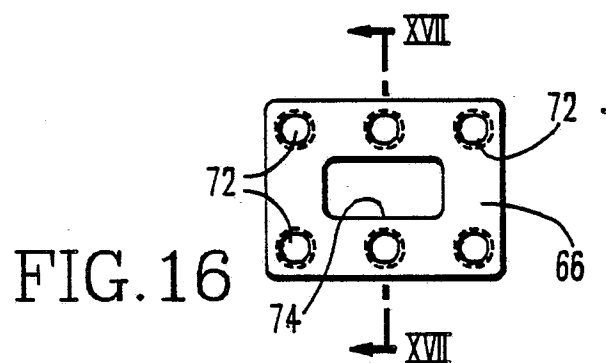
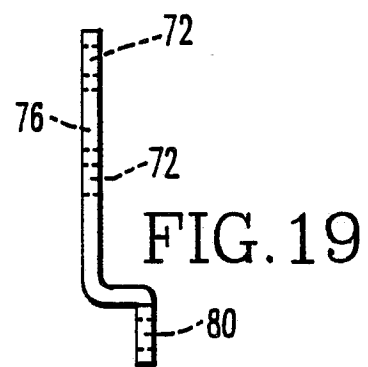
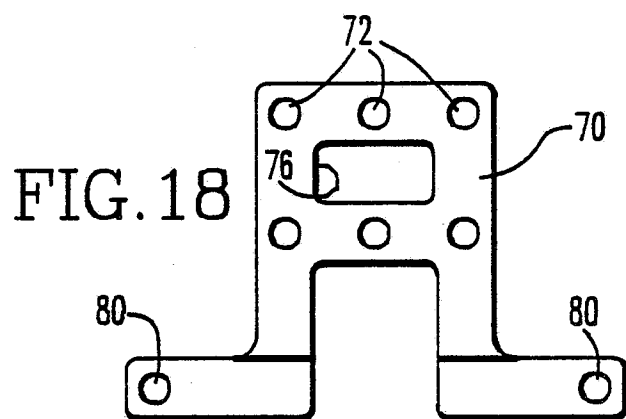
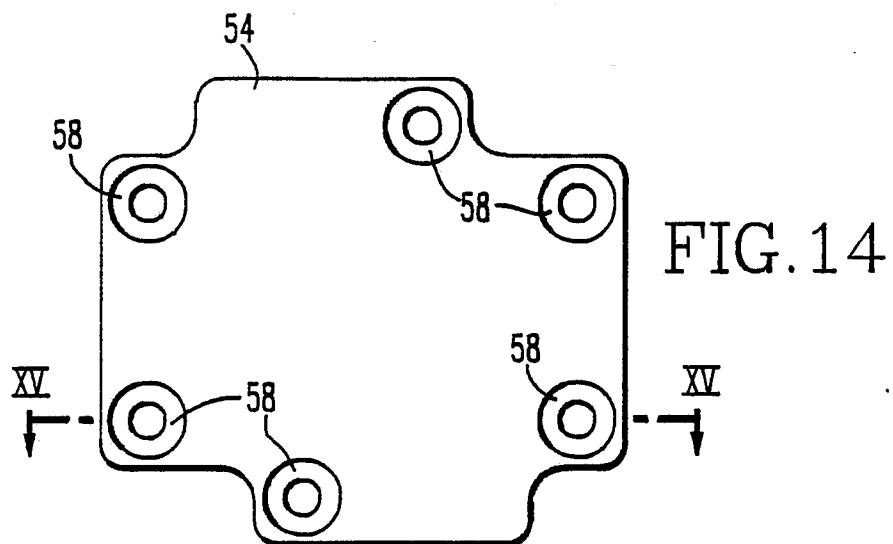


FIG. 11





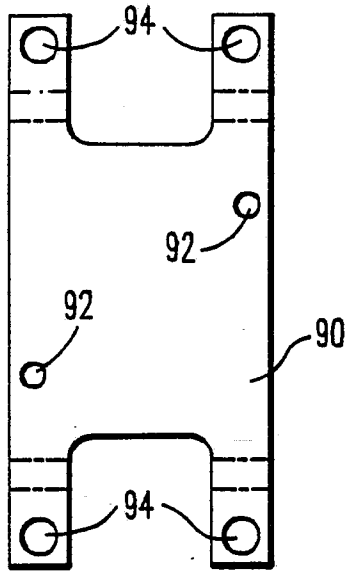


FIG. 20

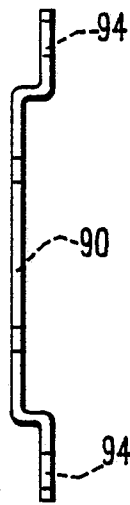


FIG. 21

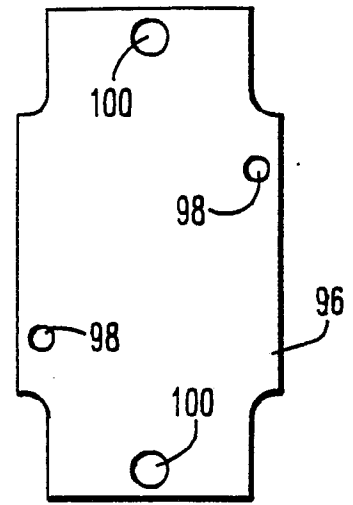


FIG. 22

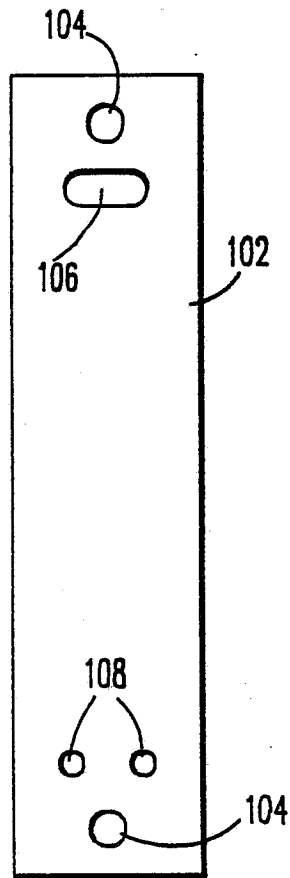


FIG. 23

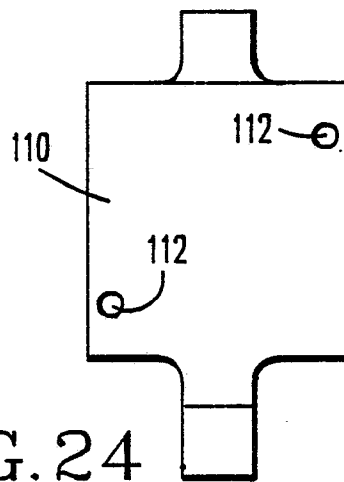


FIG. 24

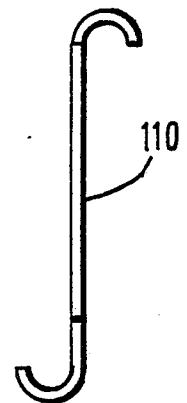


FIG. 25

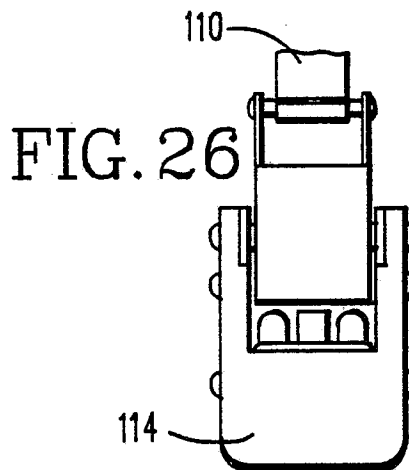


FIG. 26

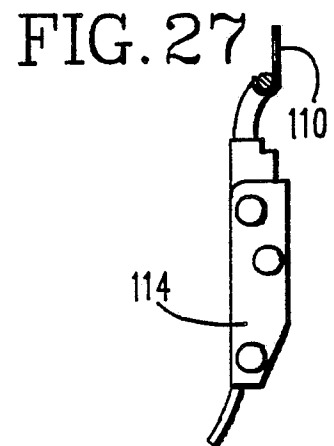


FIG. 27

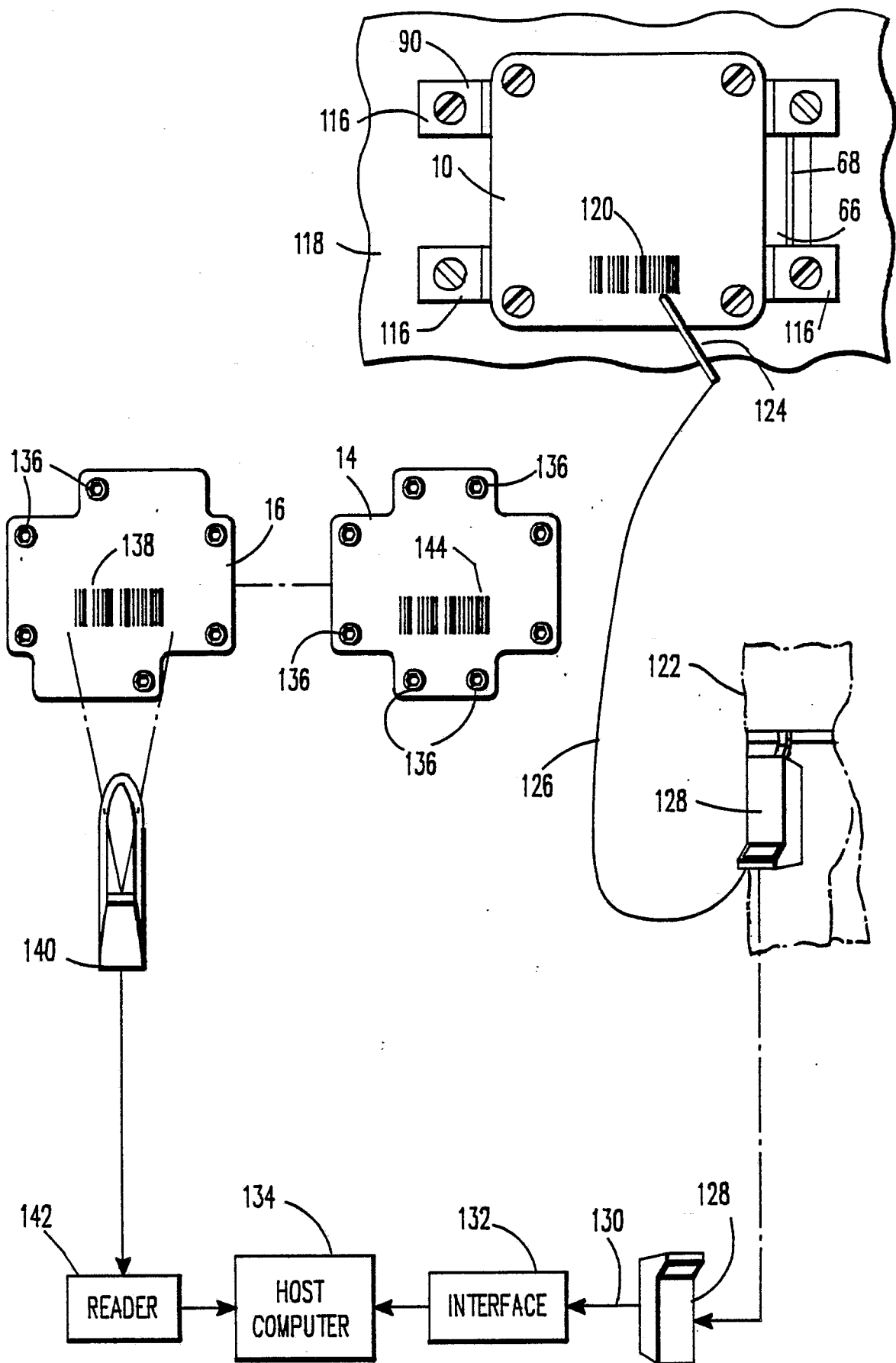


FIG. 28